Proceedings of Meetings on Acoustics

Volume 30 http://acousticalsociety.org/

Acoustics `17 Boston

173rd Meeting of Acoustical Society of America and 8th Forum Acusticum
Boston, Massachusetts
25-29 June 2017

Noise: Paper 4aNSa6

Correlating transportation noise frequencies with ultrafine particulate emissions by source: Implications for environmental health studies

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Transportation-derived particulate matter and chronic ambient noise exposure frequently occur concomitantly in urban areas, adversely impacting population health outcomes. Noise is identified as an important confounder in epidemiological studies, yet few health studies have included both air pollution and noise in health effects models. Several noise exposure studies have associated intensity and duration of transportation noise with chronic health effects; comparatively few studies have assessed airborne particulate concentrations with co-exposure to transportation noise of specific frequency. This study will present methodologies for the measurement, visualization and analysis of traffic-noise frequency and particulate emissions developed through concurrent sampling at two Greater Boston locations under varying meteorological conditions. We present methods for evaluating co-located measurement of both transportation noise and associated particulate emissions, with emphasis placed on Ultrafine Particulates (UFP, <100nm diameter). The goal of the paper is to develop a framework for a preliminary model demonstrating correlations between transportation source noise frequencies and UFP and to explore how such a result can be leveraged within future health studies.

Published by the Acoustical Society of America

1. INTRODUCTION

Particulate matter (PM) from transportation sources and ambient noise occurs concomitantly; very few epidemiological studies have included both air pollution and noise in health effects models due to a number of factors, including demonstration of causal mechanisms and confounding factors in noise and air pollution sampling methodologies (Babisch & others, 2002). Only a few recent epidemiologic studies have controlled for both variables (Beelen et al., 2009; de Kluizenaar, Gansevoort, Miedema, & de Jong, 2007; Fuks et al., 2011; Huss, Spoerri, Egger, & Röösli, 2010).

Given the presence of simultaneous exposure it is difficult to separate PM and noise-related health effects. Epidemiological studies have linked both noise and air pollution to common adverse health outcomes such as increased blood pressure and myocardial infarction, with some evidence of pulmonary function also compromised by the combined effects of air pollution and noise stress (Allen et al., 2009). In urban settings, noise and air pollution share important sources, most notably for this paper – road and rail traffic. Exposure studies of cardiovascular and pulmonary endpoints implicating both noise and air pollution as mechanisms for physiological and epidemiological outcomes may require more sophisticated exposure assessments involving measurements and/or models of both variables (op. cit. Allen et al., 2009). Assessing the presence and absence of the concordance of these highly cross-correlated variables presents opportunities for disentangling the combined impacts of traffic noise and traffic-related air pollution impacts on health.

This paper will present a methodology assessing the correlation between sources of transportation noise and concurrent PM emissions. This analysis is based upon selected vehicle noise measurements from two Greater Boston, Massachusetts communities, analyzed for noise intensity and frequency, and compared with traffic exhaust PM emissions. The short-term (< 30 second to 5 minute) measurement of spectral noise analyzed via Discrete Fourier Transforms (DFT) and spectrograms linked temporally to PM measured from transportation-source exhausts, with emphasis on ultrafine particulates (UFP) are the analytic core of this paper. UFPs, which are defined as particles that are ≤ 100 nanometers in aerodynamic diameter (< 100 nm). Given their small size, UFPs contribute little to the mass of PM in ambient air, but they are the dominant contributors to particle number count (PNC). Motor vehicles, especially those powered by diesel engines, have often been cited as a leading source of ambient UFP emissions and of deleterious effects on human health.

The goal of this research is to answer the question: Are traffic-specific pollution indicators such as UFP emissions and transportation-source noise frequencies needed to properly assess noise and particulate air pollution with respect to their potential impacts on human health? Recent studies suggest that measures of acoustical power relate more strongly than audible acoustic energy to noise perception and annoyance as well as to the non-auditory impacts such as physiological and psychological outcomes (Roberts, 2010). In this study we will identify attributes of acoustic parameters that provide improved concordance with specific sources of transportation emissions. We will characterize noise exposure using multiple quantifiable features of the vehicle noise measurement study data– notably the frequency content but also features such as modulation, overtones, Doppler effects, etc. - rather than solely overall audible acoustic energy measured as A-weighted Sound Pressure Levels (SPL).

Our hypothesis is that a model using traffic-noise frequencies as an indicator of ambient levels of UFP could be utilized to predict UFP exposures to near-roadway receptors under varying meteorological conditions. Given that this relationship is at present not wellunderstood, a further objective of this work will be to provide insight into how the impacts of noise and air pollution, which are at present viewed as being confounded, may be distinguished. In this paper we aim to evaluate whether varying meteorological parameters (wind speed and direction) are associated with order of magnitude variations in UFP concentrations emitted from transportation sources identified spectrally to aid in de-coupling human receptor impacts from concurrent noise and PM exposures.

An important contribution would be the identification of noise sources by class of vehicle (i.e. heavy trucks, trains, airplanes, buses or other diesel utility vehicles) uniquely based on their dominant noise frequency and to link this identification to the corresponding real-time measurement of PNC as a proxy for UFP. Another important contribution of this research would be to disentangle noise and air pollution by identifying scenarios of wind speed/direction and other meteorological parameters that are more likely to produce concordance in contrast to meteorological scenarios that would not. Implications from this research may support transportation engineering and urban planning initiatives for near-highway or near-railway noise control and design of improved heating, ventilation and air conditioning (HVAC) systems in housing stock exposed to both noise and PM.

2. METHODS

Tufts University (Medford, Massachusetts) researchers in Civil and Environmental Engineering (CEE), in collaboration with the Volpe National Transportation Systems Center, Environmental Measurement & Modeling Division, US Department of Transportation (DOT), Cambridge, MA planned and implemented a field data collection program that included data quality assurance and data analysis of noise monitoring instrumentation co-located with condensation particle counters (CPC) in two Greater Boston communities impacted by vehicle and transportation-related air pollution. A field data collection protocol was prepared for two continuous noise monitoring instruments co-located with two existing CPCs installed at 4 Gerrish Ave., Chelsea, MA and at the EPA Speciation Trends Network site, 1157 Harrison Ave., Roxbury, MA (Fig. 1). Both sites are being used as part of the Tufts-led Community Assessment of Freeway Exposure and Health Study (CAFEH).

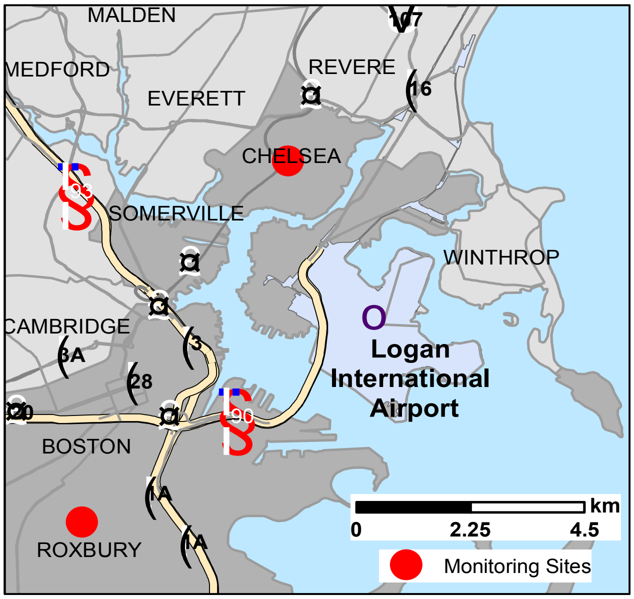

Fig. 1 Monitoring Site Locations

The noise monitoring program under this campaign began in the spring of 2016. Particle number concentration (PNC) measured via CPC analyzers and meteorological data collection at both sites had been in progress through 2015 into 2016, and continued with co-location of PNC/meteorology and noise analyzers beginning April 15, 2015. Establishment of a suitable instrumentation setup location was based on predetermined criteria, e.g., sufficiently removed from constant noise sources such as forced air vents (HVAC units) and A/C power outlets. At the Chelsea site, a secure rooftop location approximately 18 meters above street level was utilized for deployment. For the Roxbury site, a fenced-in, street-level area was utilized, with A/C power and site security.

Noise monitoring was conducted with a Larson Davis 831 (LD-831) sound level meter, Larson Davis PRM831 preamplifier and a G.R.A.S. ½", free-field, pre-polarized microphone with a microphone/preamp holder. Microphones were mounted on a portable tripod and fitted with outdoor windscreens and routed with an 8 meter LD microphone cable through a Roland R-05 Digital Audio Recorder. Noise was sampled by the LD-831 instrument at a 1 Hz and stored on the LD-831 internal memory between data downloads. LD-831 data collected includes A-weighted, Z-weighted (flat) and fast time-weighted measures of sound pressure levels (SPL), maximum Z-weighted and fast time-weighted SPL and 1/3 octave band from 6.3Hz to 20kHz. Recorded, raw sound was sampled by the Roland R-05 recorder at a 44.1kHz sampling frequency and written to 32 GB SDHC cards. Given the large quantity of audio data, waveforms were saved as .mp3 with a high bit rate (320 kbps) to preserve as much data as possible while at the same time managing file size.

Prior to equipment deployment, the LD-831 was field-calibrated with a B&K 4231 sound level calibrator and ½" microphone simulator. Weekly calibration checks were conducted at both sites under the same protocol. Recorded sound was visually field-checked and logged at both sites on a randomly selected day during the study to ascertain and confirm real-time A-weighted SPL levels of observed transportation sources (trucks, trains, aircraft).

The National Institute of Standards and Technology (NIST) atomic clock ("NIST US Time:," n.d.) was used as reference for Eastern Standard Time (EST) to set the LD-831 internal clock. LD-831 units were time synchronized with the CPC and meteorological data collection units which were also calibrated once per week using the NIST atomic clock. Drift logs were maintained for LD-831 and R-05 units, CPC units and meteorological data collection units (Table 1) based on known drift of approximately 1 minute per week for CPC units, and 1 second per day for LD-831 per manufacturer's specifications.

Meteorological data were collected on-site at both locations with a Davis VantagePro weather station, which collected 5-minute averaged data, with an internal clock reset conducted weekly (once per week). Internal clock time of the CPCs was subject to more extreme drift, possibly due to temperature effects on clock timer oscillation. An instrument clock drift adjustment for time-series plotting of all three parameters of interest was applied using an algorithm discussed in the Results section and noted in the Discussion section as a study limitation.

Table 1 Drift Logs (Excerpt) for Field Instrument Internal Clocks

Secs. v. NIST	Chelsea, MA Site				Roxbury, MA Site			
Date 2016	**LD-831**	**Roland R-05**	**CPC-3783**	**Davis MET**	**LD-831**	**Roland R-05**	**CPC-3783**	**Davis MET**
7/28	-76	65	-39	reset to NIST	72	65	-25	reset to NIST
8/8	-87	85	-101		76	80	219	
8/15	-93	105	-38		78	90	-23	
8/19	data not downloaded				79	6	-37	
8/29	-115	40	0		3	17	-34	
9/2					4	5	-48	
9/7	-7	28	-51		data not downloaded			
9/9	data not downloaded				8	17	-70	reset to NIST

Particulate measurement was conducted using a water-based condensation particle counter (CPC; TSI Model 3783). The number concentration of particles (PNC) between 7 and 3000 nm in diameter was measured every second and both 30 second and 5 second averages were recorded. The CPCs were installed in weather-proof shelters within 2 meters of the noise monitors. PNC data were collected weekly and checked for CPC temperature and flow errors flagged by the instrument. After each 6 week measurement period, the flow rate in the CPCs was field-calibrated. Side-by-side comparisons of the CPCs deployed in the field campaign were performed in the laboratory in a previous study conducted by Tufts University in 2015 and resulted in an R^2 of 0.91 comparing the two CPC units deployed with a PM reference standard, with paired measurements differing by <10% (Padró-Martínez et al., 2015).

Raw data files were downloaded weekly from each instrument – LD-831, Roland R-05; TSI Model 3783CPCs and Davis VantagePro. Data were collected for a 150-day period (5 months) and was stored and archived on replicate 1 TB external storage drives. Data files were imported into MATLAB® R2017(a) computational engineering software ("The MathWorks, Inc.," n.d.) for analytics and data visualization using a MATLAB reader script, coded to import .dat, .csv and .txt raw data files and import instrument data as tables with date, time and parameters of interest appropriately formatted for time-series plotting, noise analytics and spectral analysis.

3. RESULTS

Fig. 2 shows both wind speed (kilometers/hour) and wind direction (compass degree bearings) at the Chelsea site for a selected week in August 2016 during the noise sampling campaign. Figs. 3 and 4 suggest that both sound pressure levels (SPL) and noise frequency measures, dependent on wind vector data and other meteorological conditions, may correlate with the relative level of UFP, measured as PNC (particles/cm^3). To make these figs. we analyzed a sound audio file recorded at the Chelsea site, which is situated adjacent to a Massachusetts Bay Transit Authority (MBTA) Commuter Rail train line, approximately 4 km NW of Logan International Airport and approximately 4 km E of Interstate Route 93. Figs. 3 and 4 provide data as measured for a selected time period during August 2016, illustrative of typical diurnal and peak noise levels as PNC. These figures show PNC in the upper panels and A-weighted, average sound pressure levels (as LAeq) in the lower panels of Fig. 3 and Fig. 4.

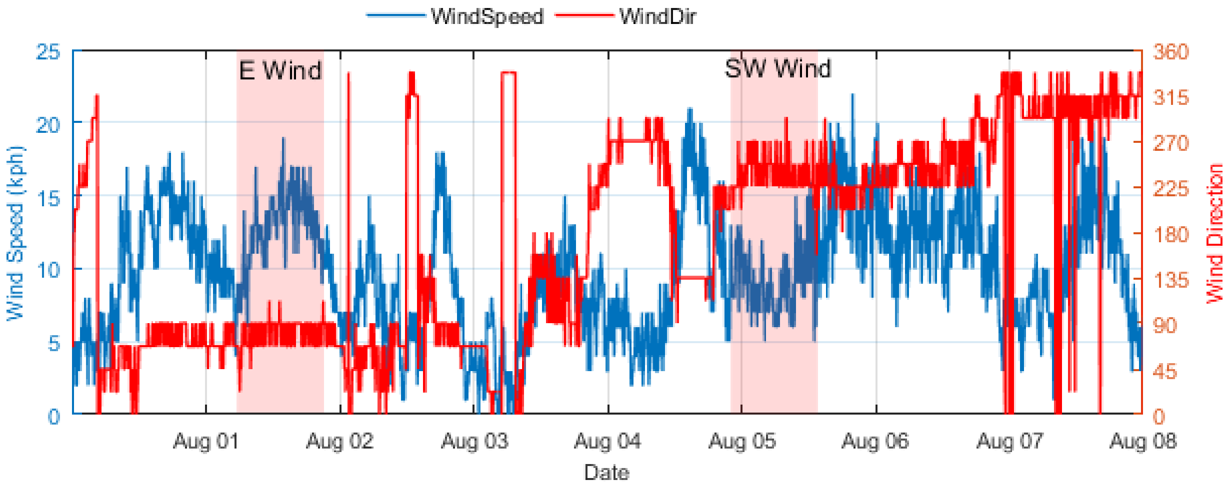

Fig. 2 Time-Series Plot of Wind Speed and Direction – Chelsea Site Jul 31 -Aug 8, 2016

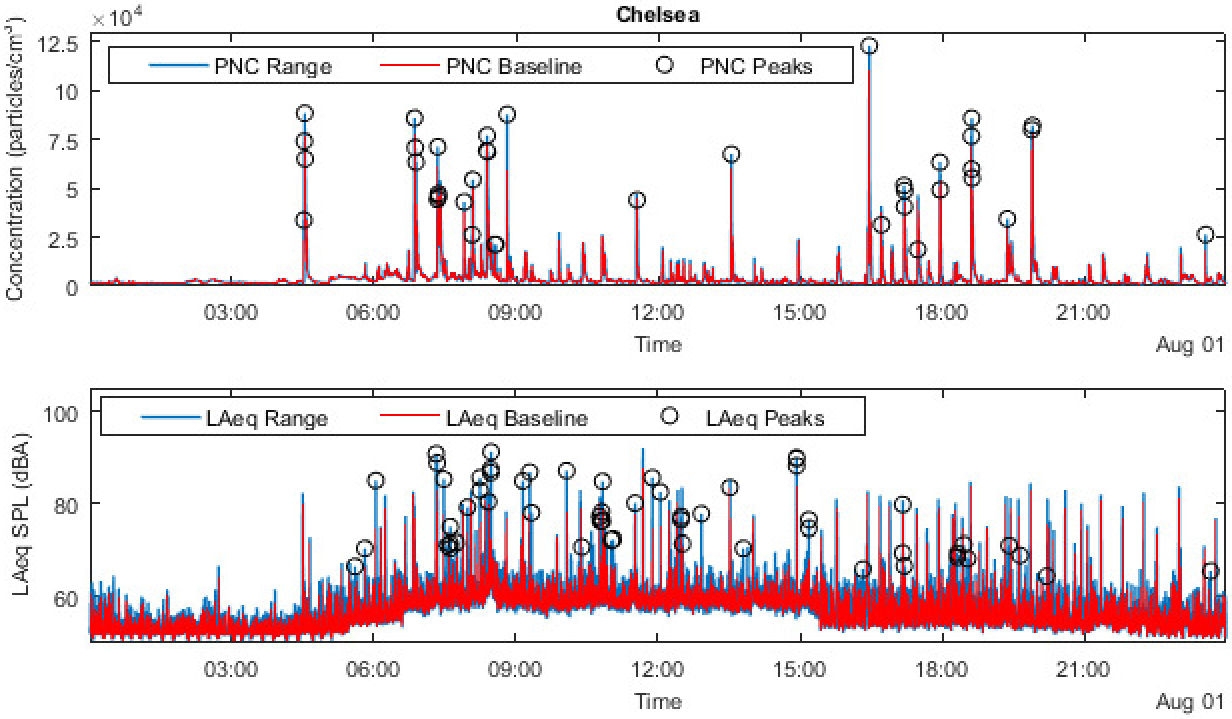

Fig. 3 Plots of Noise (LAeq) and PNC - Chelsea Site August 1st, 2016

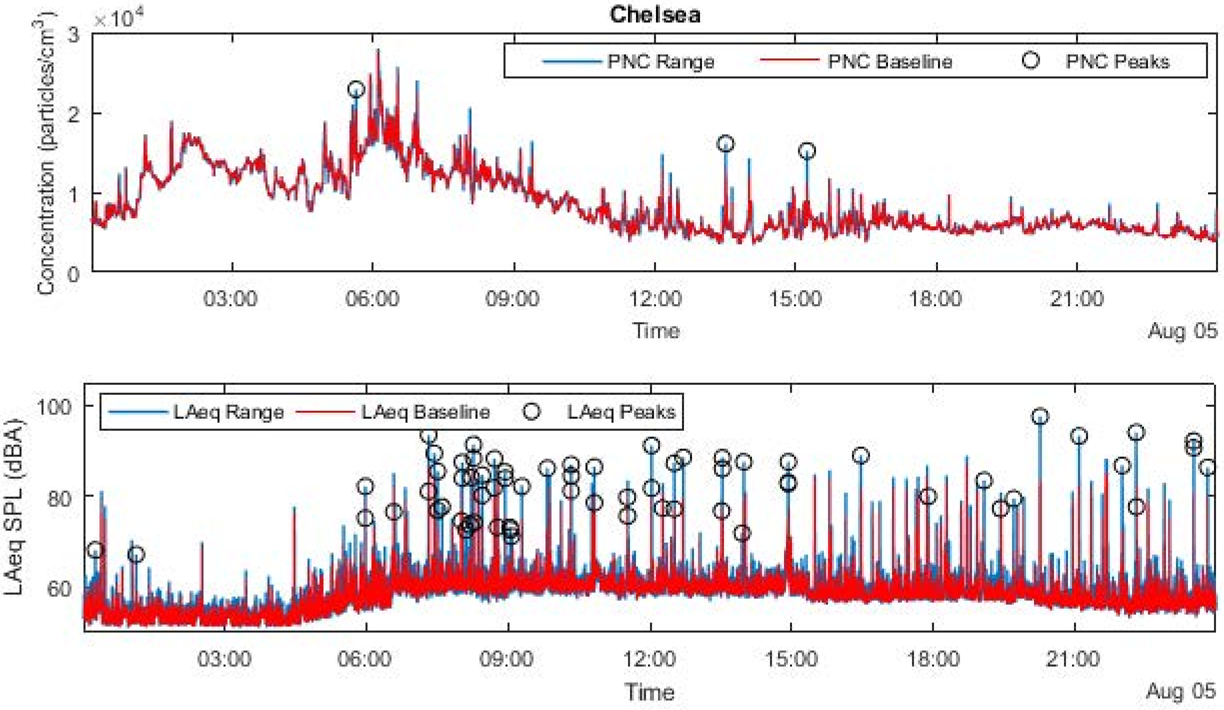

Fig. 4 Plots of Noise (LAeq) and PNC - Chelsea Site August 5th, 2016

Fig. 3 (upper panel) shows a trend of increasing PNC concurrent with increasing trends in diurnal noise measurements, plotted here as LAeq SPL (Fig. 3 – lower panel). As early morning and late afternoon traffic volume increases, corresponding peaks in PNC are noted, with a mean PNC value of 4.1x10^3/cm^3 and median PNC of 2.3x10^3/cm^3 for the August 1st sampling date with wind direction from 090 degrees (annotated "E Wind" on Fig. 2) and wind speeds varying from 4 – 19 kph (median wind speed 12 kph). On the Friday August 5th sampling date, wind directions shifted to the southwest (235 degrees – annotated "SW Wind" on Fig. 2) at slightly elevated speeds of 5 -22 kph (median wind speed 11 kph), yet mean PNC increased by a factor of two to 8.6x10^3/cm^3 and median PNC increased by a factor of three to 6.9x10^3/cm^3 while August 5th LAeq noise levels as follow similar diurnal trends as August 1st. On August 1st, the mean LAeq level was 72.5 dBA and the maximum was 95 dBA, compared to a mean LAeq level of 75.3 dB and maximum of 100.5 dBA.

LAeq and PNC peaks are flagged as small circles in Figs. 3 and 4 and based on the window size (number of data points). A threshold function in the MATLAB code defines the tolerance in terms of standard deviation, for example, 2.0 for LAeq, 0.75 for PNC raw data, and 1.5 for LAeq and 0.25 for PNC averaged/resampled data. The MATLAB code identifies a peak (flagged as a circle) if the data point is at least threshold x standard deviation (stddev) above the moving mean, and its value is greater than its neighboring data points, assessed using the difference of the current data point from the points prior and following. A positive gradient prior to a data point and a negative gradient following the data point would identify it as a peak point provided it is threshold x stddev above the moving mean.

If a peak point occurs for both LAeq and PNC simultaneously, it is categorized as a coincident peak. An algorithm in the MATLAB code generates a table of LAeq and PNC coincident peaks by time as an Excel file. Using the "VLOOKUP" function in Excel, the table can be sorted to find corresponding times of SPL peaks (LAeq) with PNC peaks to an approximate match in Excel, thus allowing longer scale time-series data to be analyzed for more focused, short-term occurrences of peak noise for frequency domain analysis. Table 2 shows an excerpt from the Excel file, and several coincident matches by time can be seen in the far right column titled Coincident Peaks, shaded by color to indicated an approximate time-series concordance.

Table 2 Coincident Raw Peak Identification by Time –Noise (LAeq) and PNC – Color Matched

RawPeaks LAeq	RawPeaks PNC	Coincident Peaks
8/1/2016 7:36	8/1/2016 6:52	
8/1/2016 8:28	8/1/2016 7:19	8/1/2016 8:28
8/1/2016 9:08	8/1/2016 8:32	
8/1/2016 11:30	8/1/2016 8:33	8/1/16 11:30
8/1/2016 11:52	8/1/2016 11:32	
8/1/2016 12:54	8/1/2016 13:32	
8/1/2016 13:30	8/1/2016 16:27	8/1/16 13:30
8/1/2016 15:10	8/1/2016 17:11	
8/1/2016 17:11	8/1/2016 17:12	8/1/16 17:11

By utilizing MATLAB computational engineering software, recordings of traffic noise samples were analyzed using the Fourier transform to convert waveform data in the time domain into their frequency domain equivalents. Converting to the frequency domain, the discrete Fourier transform (DFT) of the noisy signal was found by taking the Fast Fourier Transform (FFT). DFT analysis was conducted on several selected traffic noise samples, illustrative of common traffic and transportation sources in the effort to:

1.) establish a framework for predictive association between traffic "background" noise frequencies and UFP in vehicular emissions exhausts

2.) associate empirical data on UFP with trucks, buses, and other diesel-exhaust vehicles operating at dominant on-road frequencies

Using this approach, we analyzed the spectral characteristics of a selected PNC peak coincident with a dBA noise peak on August 1st, 2016 at the Chelsea site. Table 2 displays a dBA peak at 08:28HRS with a peak noise level of 92dBA and a corresponding PNC peak of $9.0\text{x}10^4$/cm3 (Fig. 3). Spectral analysis of recorded sound during the associated time of 08:28HRS from Table 1 is presented in Figs. 5 and 6.

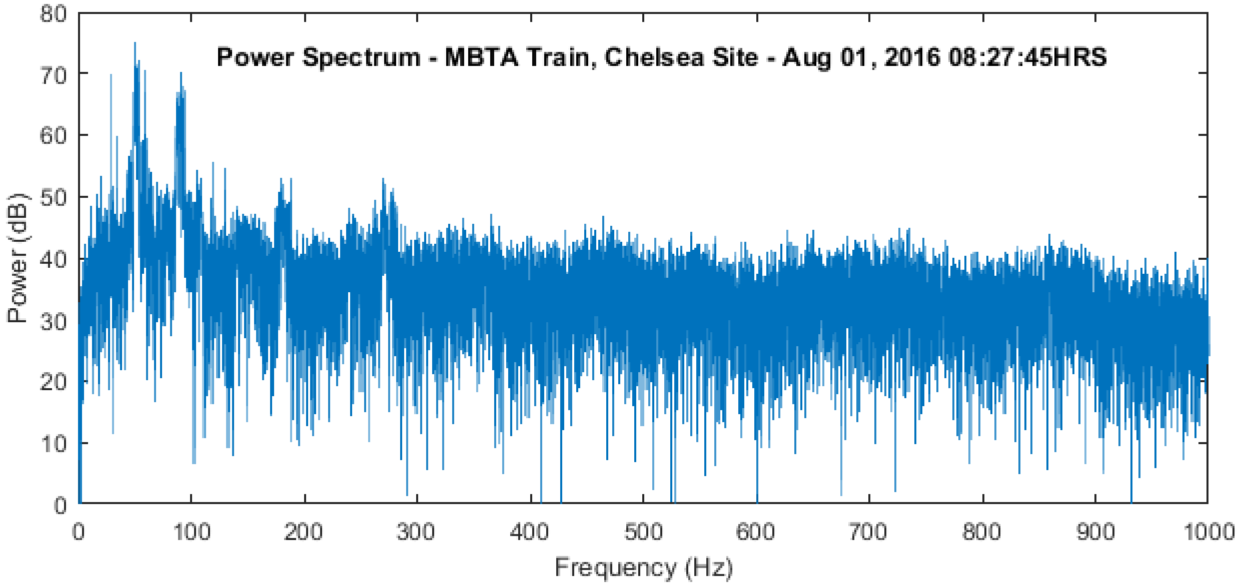

Fig. 5 Power Spectrum for Selected Noise Sample (MBTA Train)

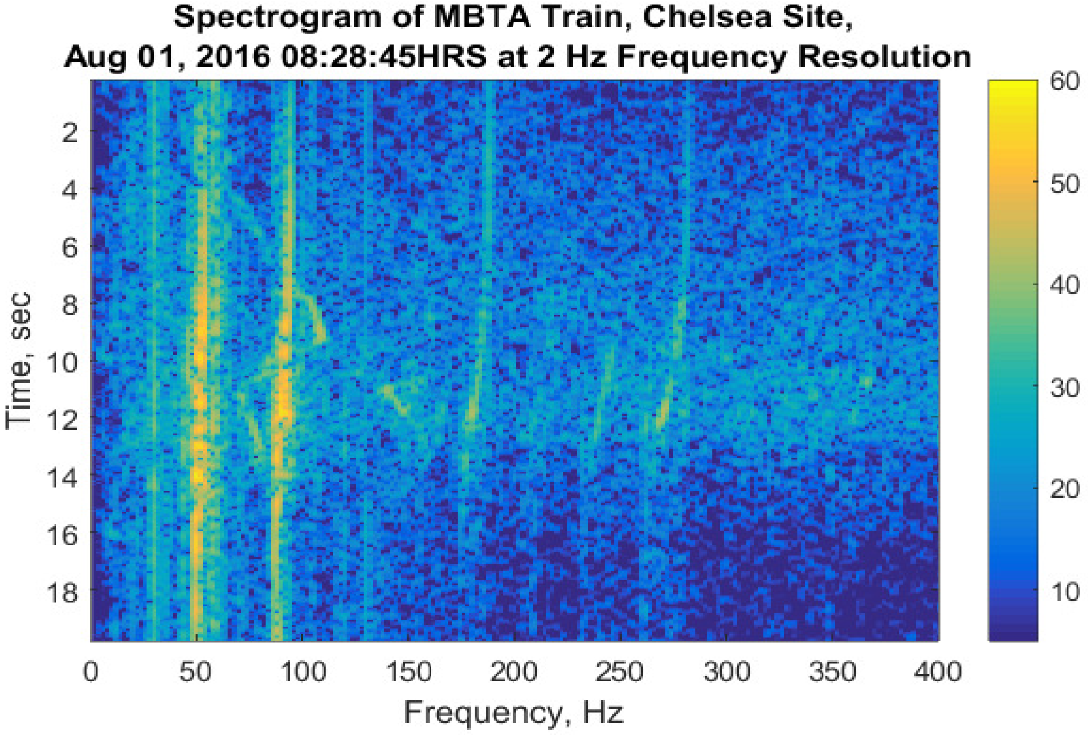

Fig. 6 Spectrogram of Passing MBTA Train Showing Doppler Effect and dBA (color bar)

Figs. 5 and 6 (taken together) allow for a spectral analysis of a commuter train as it passed the PNC and noise monitoring analyzers at the Chelsea site. A train schedule obtained from the MBTA confirms the time of the train's transit. Spectral power analysis of the recorded train noise suggests a dominant frequency of 50Hz with secondary frequencies near 80, 180 and 280Hz. Fig. 6 presents a spectrogram from 0-400 Hz showing the tones in the train noise (dBA scale on y-axis) and their Doppler shift vs time.

In another example in Fig. 7, a subset of the noise data identified by the coincident peak event table as time-correlated with PNC, plotted from 50 to 80 dBA is displayed. In the dBA measurement (Fig. 7 -upper panel) there is little variation other than small fluctuations in noise intensity due to a few passing trucks, as observed visually in the field. In contrast, the 1/3 octave band (Fig. 7 -lower panel) spectra show clear differences between more distant, large trucks on the highway (low frequency) and a small pickup truck on a nearby surface road (higher frequencies), both superimposed on background noise level generated by car traffic (light blue). Because large trucks have much higher UFP emissions than smaller vehicles ("EPA 420-F08-027, Oct. 2008,".), we anticipate that low-frequency sound levels may correlate better with vehicular-derived UFP air pollution than the commonly used dBA metric.

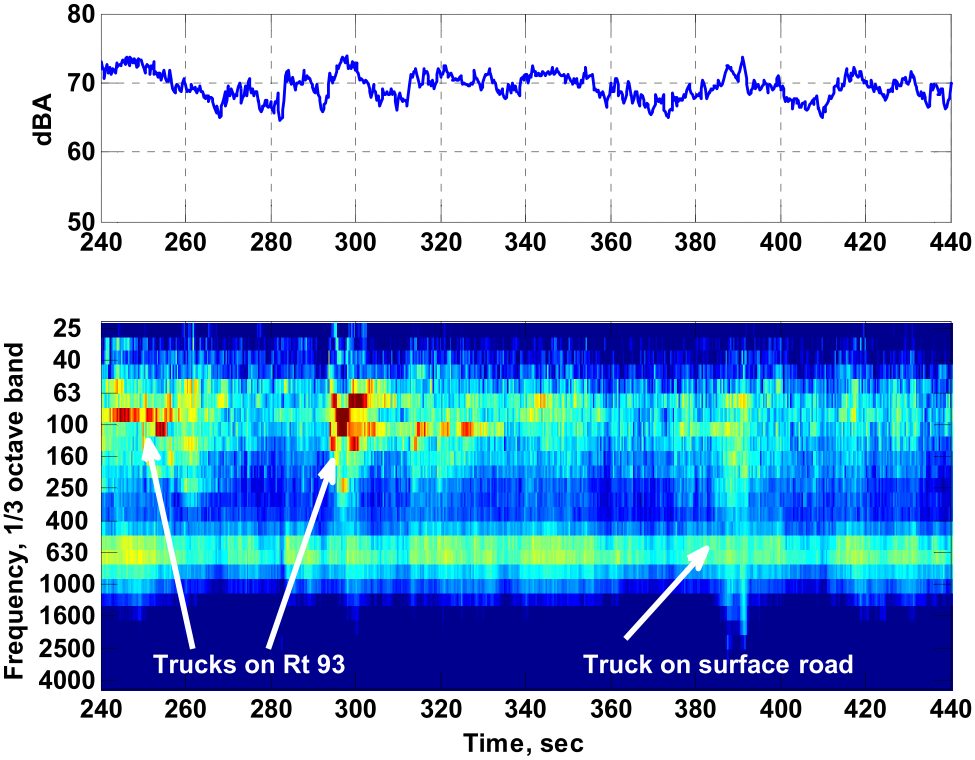

Fig. 7 Plot of Noise Levels vs. Time and Third-Octave Band Frequencies for Boston Roadway

By use of the DFT algorithm and spectrogram function in MATLAB, we are able to analyze and determine the dominant frequency of the traffic noise as centered around 50 -150Hz, which corresponds to "low frequency" band noise, with secondary and tertiary "medium" frequency bands at 200 -300 Hz and 950 -975 Hz, respectively. For this study, low frequency noise is considered 250 Hz and below; high frequency noise is 2000 Hz and above; mid-frequency noise falls between 250 and 2000 Hz ("Industrial Noise Control," n.d.).

Critical to establishing the time series of coincident LAeq and PNC data peaks was the synchronization of the internal instrument clocks to a reference time via the NIST atomic clock. Drift logs (Table 1) were maintained for LD-831 and R-05 units, CPC units and meteorological data collection units (total, 3 drift logs per site) based on known drift of approximately 1 minute per week for CPC units, and 1 second per day for LD-831 per manufacturer's specifications. Meteorological data collection unit time clocks, which collect 5-minute data, were reset once per week. CPC instrument internal clock time was subject to more extreme drift than manufacturer's specifications suggested, possibly due to temperature effects on clock timer oscillation. An instrument clock drift adjustment for time-series plotting of all three parameters of interest was performed using an algorithm in the MATLAB code, which corrected the instrument clocks to achieve agreement during data analysis.

4. DISCUSSION

Current transportation noise impact assessments are usually based on broadband A-weighted noise indicators. Although many studies have shown that A-weighting can underestimate the important role low frequency noise (LFN) plays in loudness perception, annoyance, and speech intelligibility, A-weighted SPL, or dBA (as has also been defined in this paper) has continued to be the predominant measurement descriptor for noise assessment. More importantly, the de-emphasizing of LFN content by A-weighting can also lead to an underestimation of potential harm from physical and psychological effects associated with frequency content and other characteristics of sound. Such underestimation occurs because of frequency content not being captured in the commonly used dBA scale. Notably, traffic noise contains much more low-frequency energy than is reflected in most dBA summaries (op. cit. Roberts, 2010).

Predictive models have been developed to estimate measured total particle number (TPN) adjusted for meteorological conditions for specific noise indicators (L_{2KHz} -L_{125Hz} = low to med frequency noise bands (Can, Rademaker, et al., 2011). These models have shown strong correlation (Spearman 0.62) between measured and predicted TPN based on wind speed and wind direction. A key constraint in the development and refinement of such models is the difficulty in capturing noise frequencies that are representative of traffic sources, rather than reliance on the conventional A-weighted SPL, dBA for model construction. In a recent Belgian study (Can, Dekoninck, et al., 2011) engine noise and its corresponding low frequencies (around 100 Hz) were found to predominate at both ends of the speed spectrum: – at low speeds and during accelerations, with rolling noise containing many medium frequencies (around 1 kHz), dominant for vehicles speeds exceeding 50–70 kph (op. cit. Can, Dekoninck, et al., 2011).

Based on this characterization, it is possible to identify the general traffic patterns of recorded vehicular noise relative to the frequency bands determined by FFT and spectrogram analysis of traffic noise levels. It is documented that specific classes of vehicles emit engine noise within distinctive frequency bands, largely influenced by vehicular speeds (Dekoninck, Botteldooren, De Coensel, & Int Panis, 2016). This would make it possible to segregate traffic frequencies into their respective vehicle source class – i.e. diesel engine trucks, buses vs. cars. Moreover, since particulate emissions rates (typically reported in grams/mile) for vehicles by fuel type (gasoline or diesel) are known, and often reported by the engine manufacturer and published by the EPA as a model to estimate emissions factors for different types of vehicles by weight class, developing a framework to associate vehicle noise frequencies with their respective PM emissions (op. cit. "EPA 420-F08-027, Oct. 2008.") may be plausible.

The present study would provide access to a large data set for the analysis of trends in PNC with corresponding peak noise measurements over two seasons (Spring and Summer) under varying meteorological conditions. We anticipate additional data analysis will demonstrate correlations of

PNC to vary with traffic noise levels under appropriate meteorological conditions (primarily wind speed/direction). We also believe that spectral analysis of selected noise peaks will demonstrate low frequency noise (250 Hz and below) to be correlated with higher UFP levels predominately from diesel exhaust emissions from large trucks, diesel locomotive trains and heavier gross weight vehicles, with lower UFP concentrations corresponding with high frequency noise (> 2000 Hz).

Comparing the two selected sampling dates of August 1st and August 5th, 2016 we observe that while the noise intensity levels (dBA) did not increase substantially and followed the same diurnal trend, mean PNC increased two-fold in conjunction with changes in the wind direction from 090 to 235 degrees, while there was no statistical difference in median wind speeds for both dates (p = 0.0548; Wilcoxon rank sum test). Further, the number of noise and PNC coincident peaks identified and tabulated by the MATLAB function decreased substantially, by nearly one order of magnitude in the 8/5 data set compared to the 8/1 data set. This may be indicative of the fact that it is the effect of a few random noise sources on August 1st rather than the diurnal patterns in transportation noise that influenced the magnitude of PNC peaks based on a wind direction favorable to UFP transport. The emissions transport in this case was from MBTA train diesel exhaust, as was confirmed by spectral analysis of the recorded noise peaks. Further, data suggest that the lower frequency ranges of 50 -250Hz from the passing train engine could be indicative of peak PNC levels, given a preferential wind direction for UFP transport from the emissions source to the receptor (PNC analyzer). With wind directions originating from non-localized and more continuous PM sources (e.g. cars and trucks on roadways to the SW of the Chelsea site), the pattern of diurnal noise followed an expected trend, with PNC levels increasing more gradually, peaking at 06:00HRS (Fig. 4) with the morning traffic commute. Noise levels in the latter scenario were more likely associated with localized sources, still inclusive of passing trains, but PNC was not coincident to these sources given the non-preferential wind direction.

A limitation in the data collection and analysis of this study is the MATLAB algorithm's functionality to correct for instrument clock drift. The algorithm assumes linearity of drift for a given monitoring period (e.g. 6 second drift/7 days assumes < 1 sec/day linear drift), which may not be an accurate assumption for CPC instruments as noted previously. Other limitations in this study are the absence of health data (i.e. – blood pressure, heart rate, respiration rate) for the study period from exposed receptors (residents and occupants of housing developments, neighboring dwellings, businesses and schools). However the noise and PNC data collected during the 150-day study period may be useful for assessing exposure levels at discrete distances from transportation noise and exhaust sources. If presented in the form of an exposure map or grid and coupled with human health data collected in the future, a better understanding of co-exposures to both noise and UFP could be assessed.

5. CONCLUSIONS

Preliminary analysis of selected data collected during the field campaign showed trends in concordance between low-frequency transportation noise and high levels of ultrafine particulate matter (UFP), measured as particle number count (PNC). Under specific conditions of wind direction, wind speed and other meteorological parameters (i.e. – humidity, temperature) mean PNC levels differ by an order of magnitude or more based on preferential transport of particulate matter to the CPC instruments measuring PNC, yet sources of transportation noise are measurably present regardless of meteorological conditions. Further statistical analysis of the daily (n = 150) noise v. particle count data under differing wind speeds/directions is warranted for a more complete analysis of noise and UFP correlations.

Our data set allows the development of a linear regression model with UFP concentration (or PNC) as the response variable , and could potentially be developed with noise frequency, traffic counts, proximity to roadways, meteorological conditions (wind speed, direction, temperature and humidity) as predictor variables. To our knowledge, this study is one of the longer-term data collection campaigns in which both noise and PM were continuously sampled. Many transportation noise and PM studies have focused on evaluating near-highway or urban core receptor impacts from noise (typically as dBA) and PM/UFP based on only a few weeks of data collection. The study presented herein encompasses five months of co-located noise and particulate data collection with the addition of recorded sound samples for frequency analysis for source identification via spectral analytics.

Finally, an important strength of this study is that the sites sampled – Chelsea and Roxbury, MA - are both Environmental Justice Communities as defined by the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), based primarily on EEA policy designed to help ensure their protection from environmental pollution as well as promote community involvement in planning and environmental decision-making to maintain and/or enhance the environmental quality of their neighborhoods (mass.gov). The rich data set collected in this study could be highly beneficial to development of local ordinances and policies to mitigate the dual impacts from transportation noise and air pollution on community receptors.

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